

Narrow features - Fe K Line Variability in AGN

Jane
Turner

James Reeves, Lance Miller, Ian George,
Steve Kraemer

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.



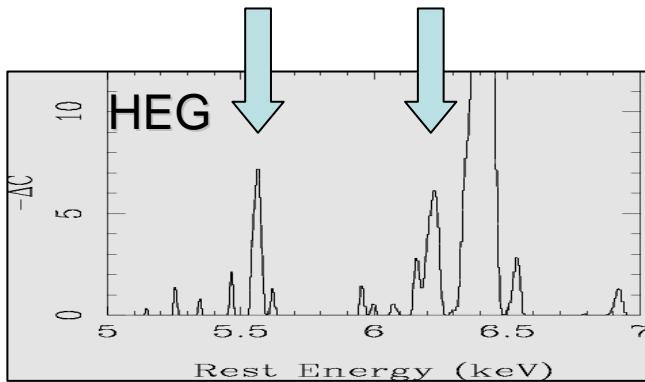
National Aeronautics
and Space Administration

What do we want from Con-X observations of AGN?

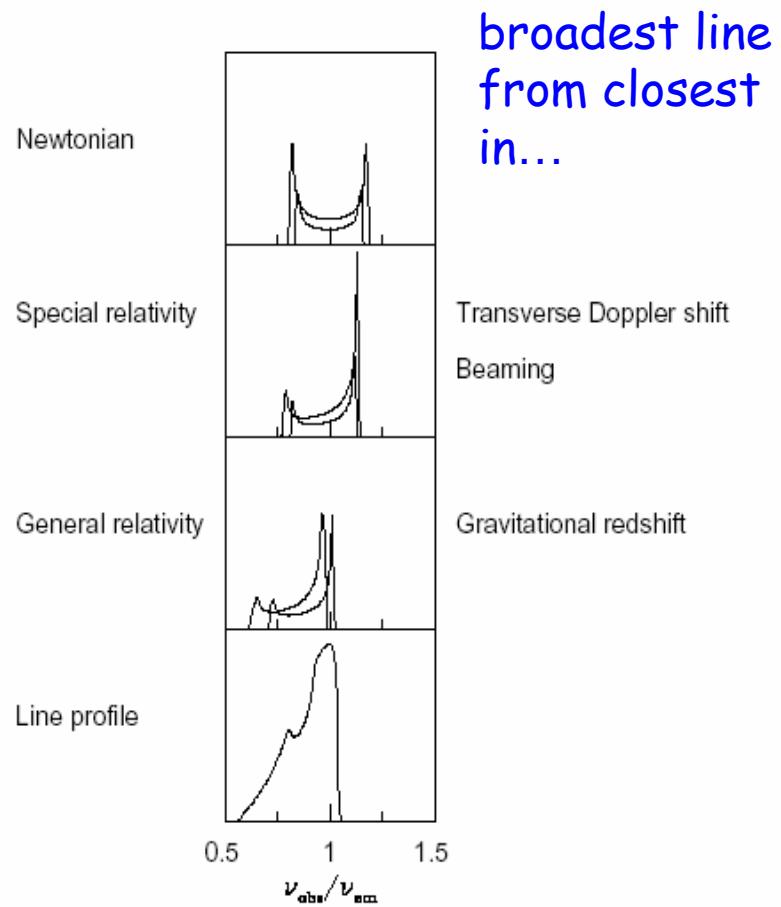
- study physics in the strong gravity regime *Fe K α*
- understand black hole accretion/expulsion (hence growth, evolution, and feedback) *X-ray absorbers*

Groundbreaking science for Con-X

➤ Strong gravity physics via study of broad line and new disk diagnostic: hotspot emission



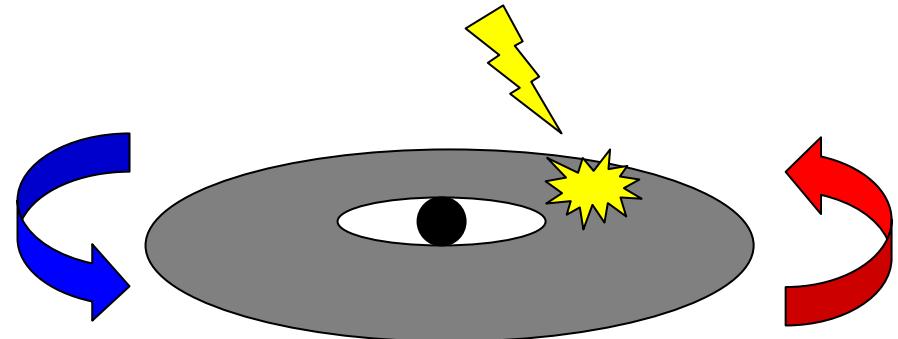
Narrow Fe emission lines, shifted from rest-energy, first obsⁿ in AGN - NGC 3516 (Turner et al 2002)



Fabian et al 2000

Groundbreaking science for Con-X

Rapid (tens of ks) flux/energy variability - must be diagnostics of gas v close to BH - likely disk hotspots



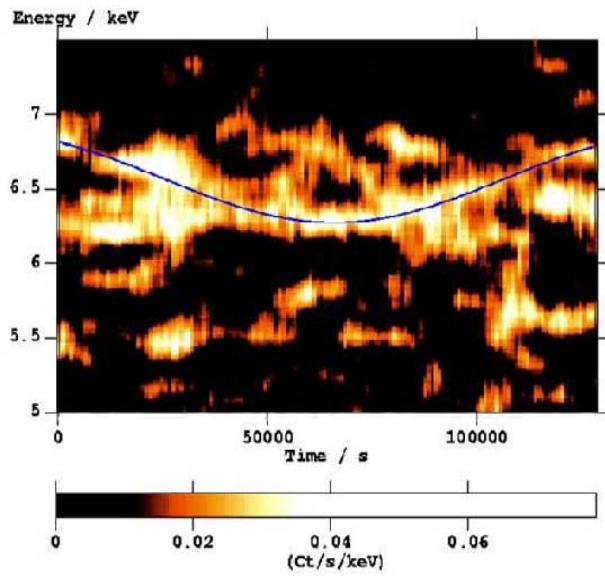
ESO198-G24 Guainazzi 2003;
NGC 7314 yaqoob et al 2003,
Mrk 766 Turner et al 2004,
Mrk 841 Loginotti et al 2004,
ESO 113 Porquet et al 2004,
4U 1344 Piconcelli et al 2006

...inferred origin tens -
hundreds of r_g

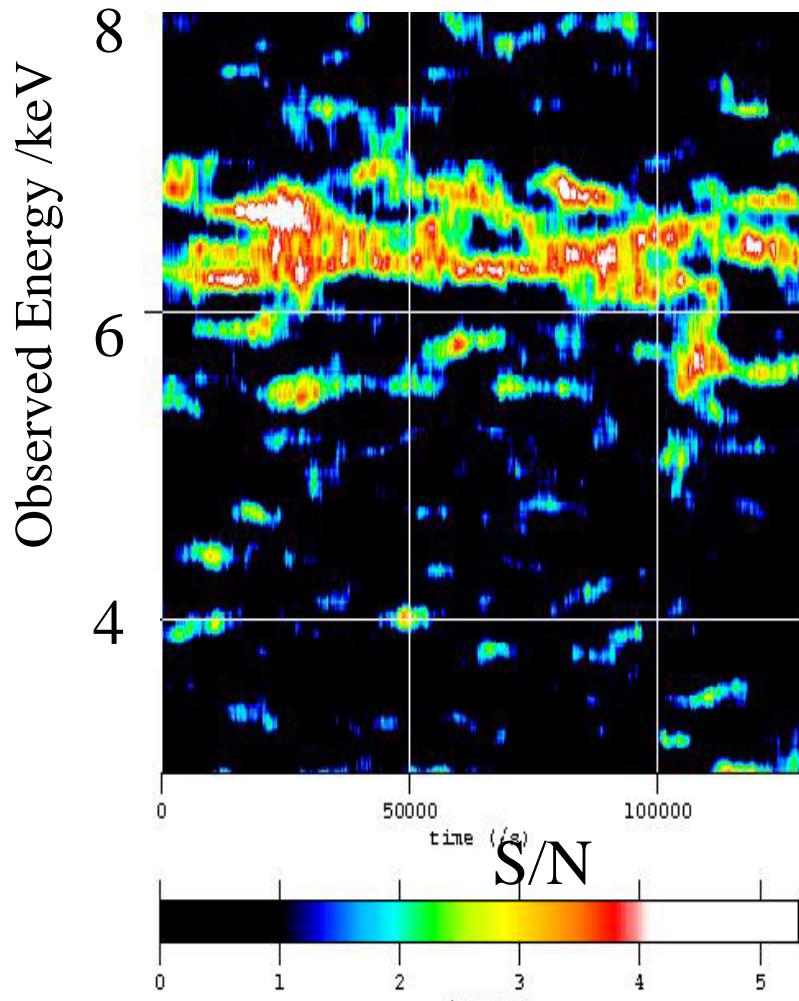
More Specific Disk Diagnostics

Doppler variations in line energy
show period ~ 165 ks

Line of sight vel $\sim 13,500$ km/s



Mkn 766 (Turner et al 2006)



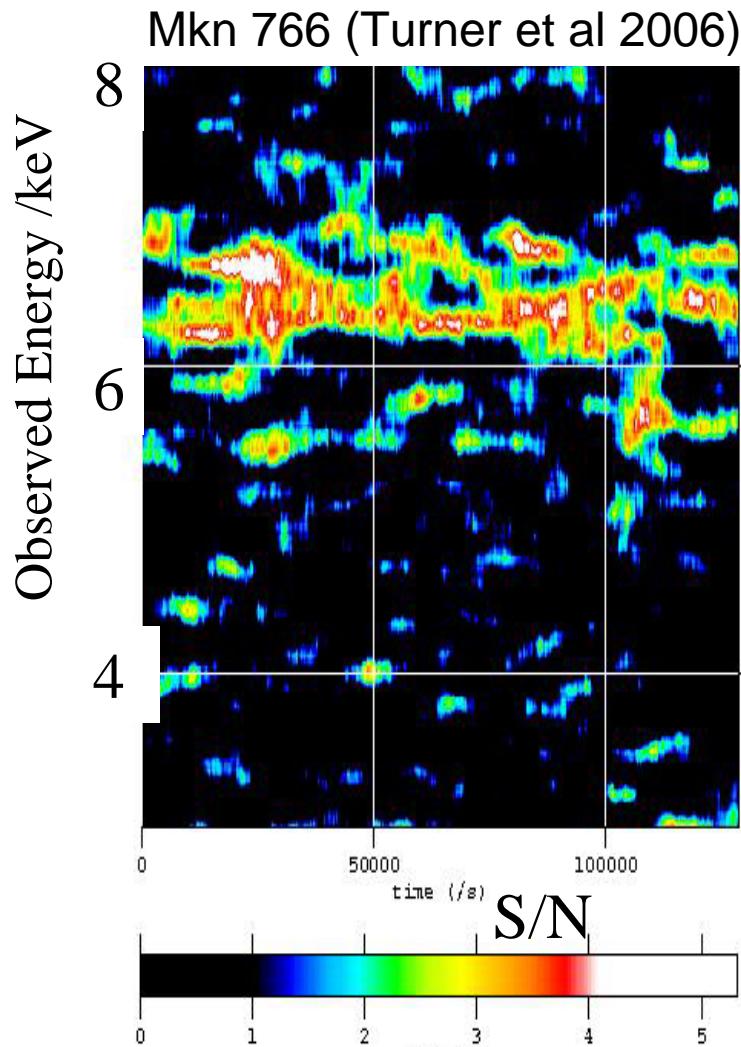
More Specific Disk Diagnostics

$$t_{orb} \approx \left(\frac{r}{9r_g} \right)^{\frac{3}{2}} M_8$$

$$\frac{\Delta E}{E} \approx \frac{v_{orb} \sin \theta}{c} \approx \sin \theta \sqrt{\frac{r_g}{r}}$$

If one assumes an inclination can get mass, or assume mass and get inclination

$M_{BH} > 5 \times 10^5 M_\odot$ exists within $3.6 \times 10^{13} \text{ cm}$



Line/Continuum Correlation

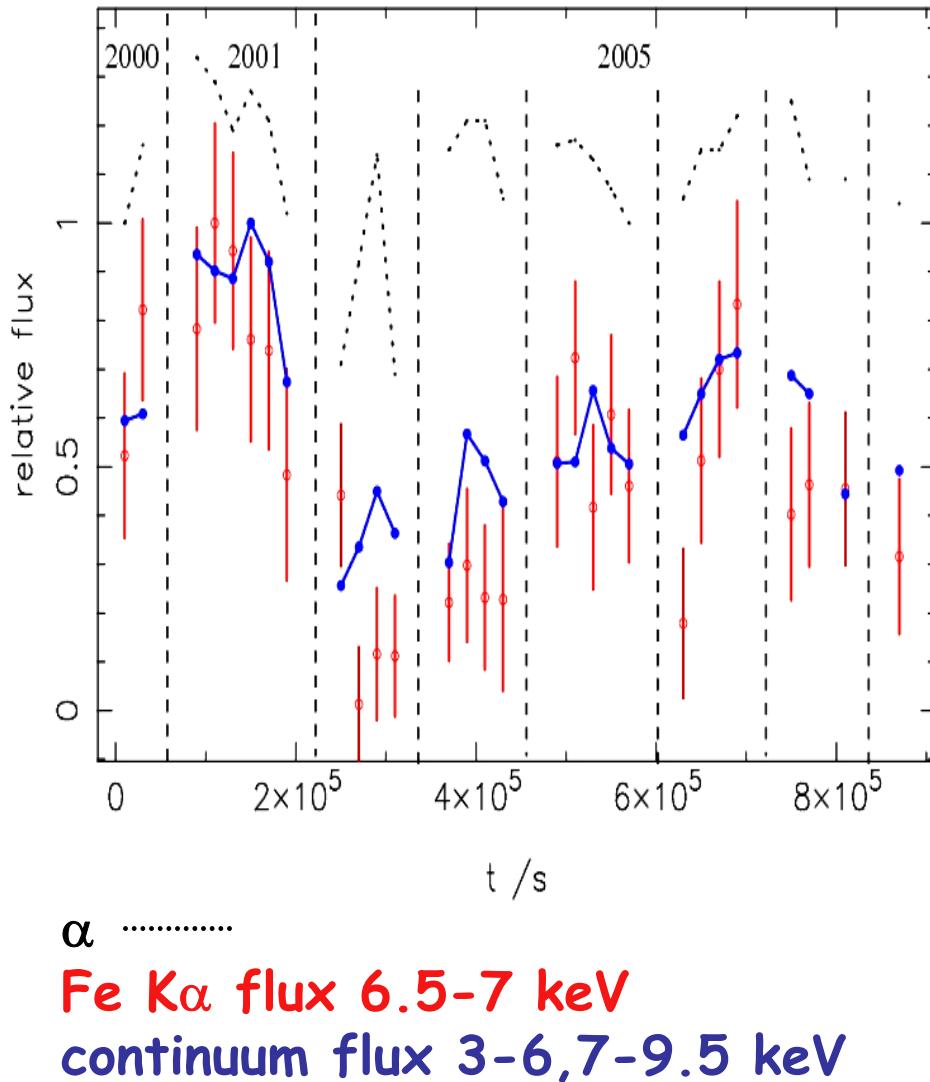
Line strength also correlates w/
continuum flux down to 10 ks -
confirms line produced v near
illuminating source

Con-X XMS will track corrln down
to ~ 3 ks

Have seen features
travelling round the disk,
and also achieved some
reverberation mapping

Can diagnose disk from
narrow Fe line variations

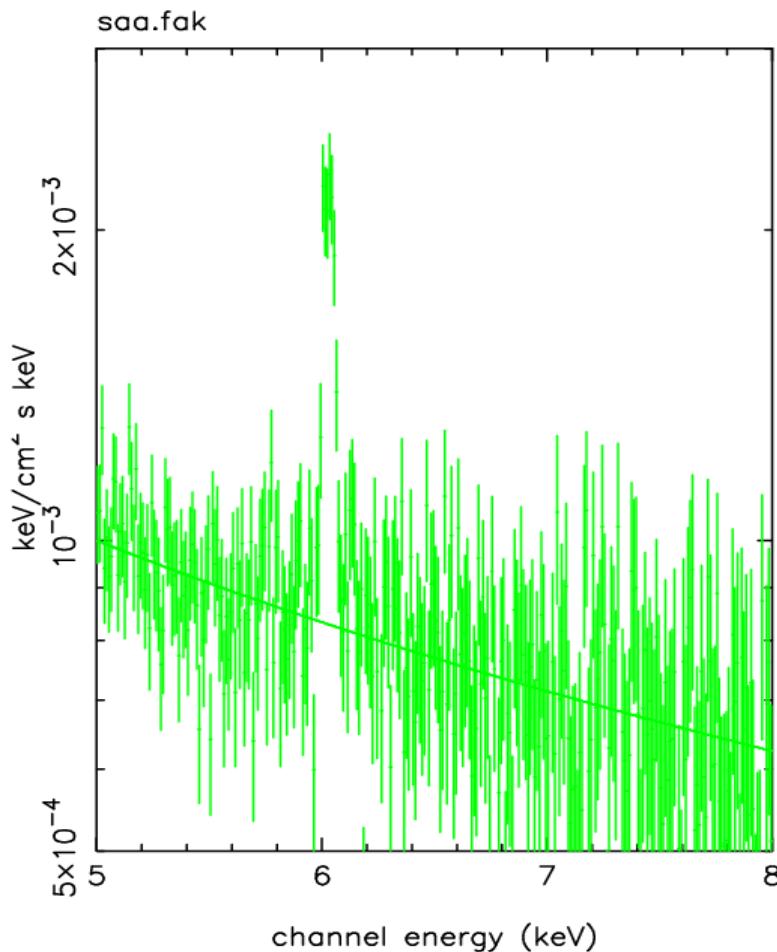
Miller et al 2006



Simulation Case 1: Mrk 766

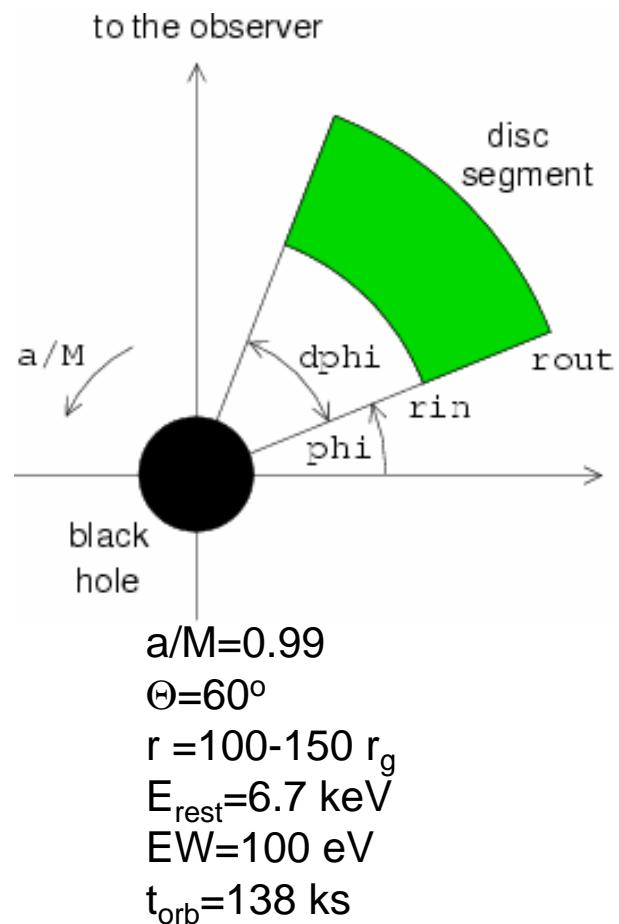
$M=4.3 \times 10^6 M_{\odot}$

$F_{2-10} \sim 1 \times 10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1}$



$\Delta\Phi = 10^\circ$ 36×4000 s sims

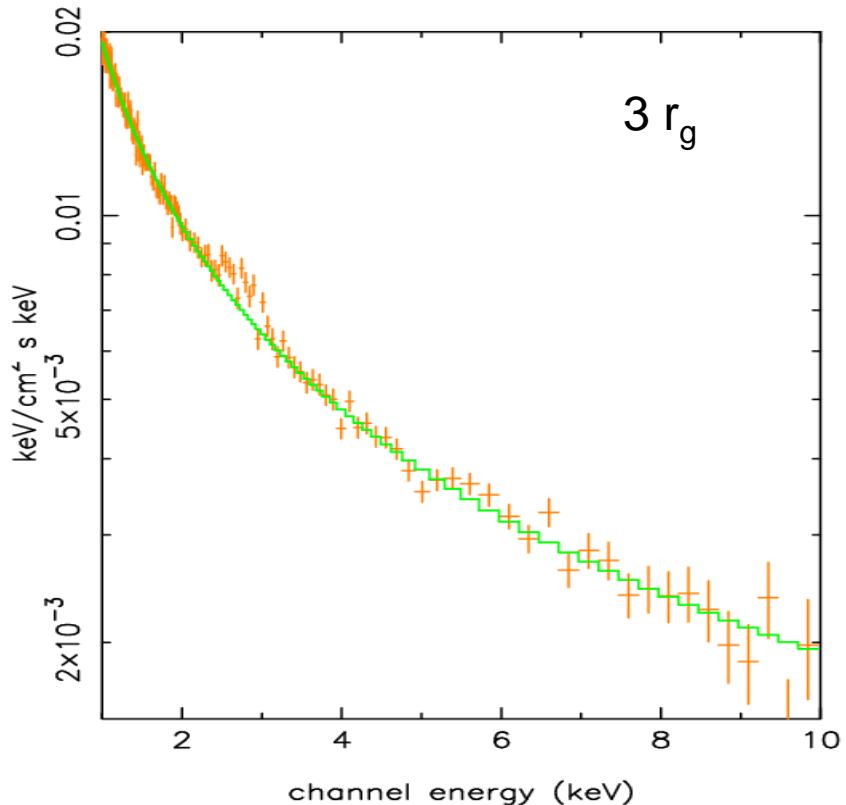
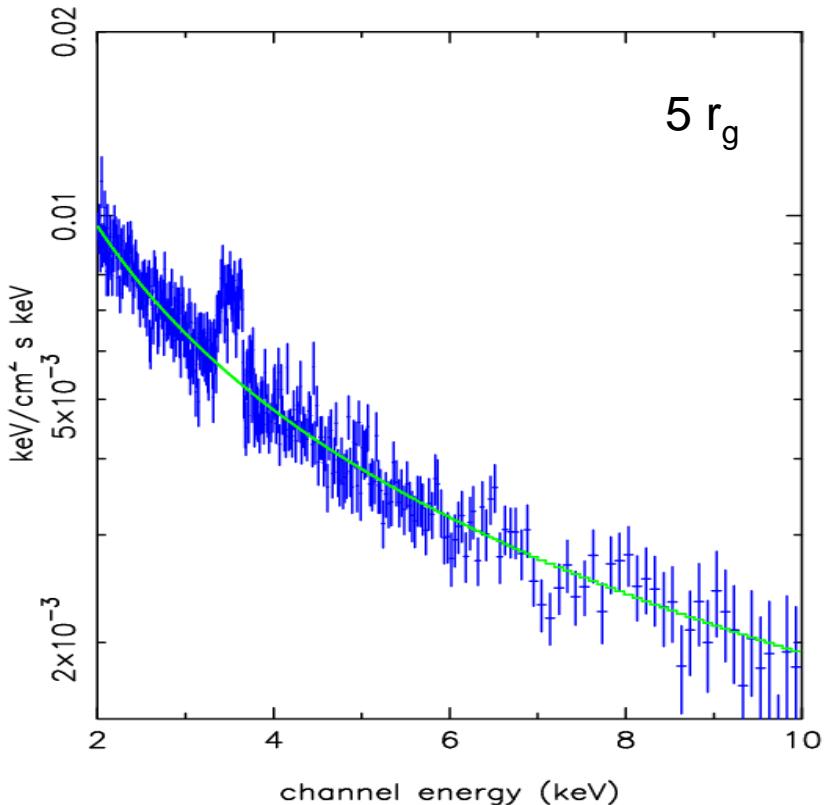
Dovciak, Karas, Yaqoob 2004-
accretion disk spectra in the strong
gravity regime



Simulation Case 2: NGC 3516

$M=2.3\times 10^7 M_{\odot}$

$F_{2-10} \sim 5\times 10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1}$



$t_{\text{orb}}=9 \text{ ks}$

$12 \times 750 \text{ s}$

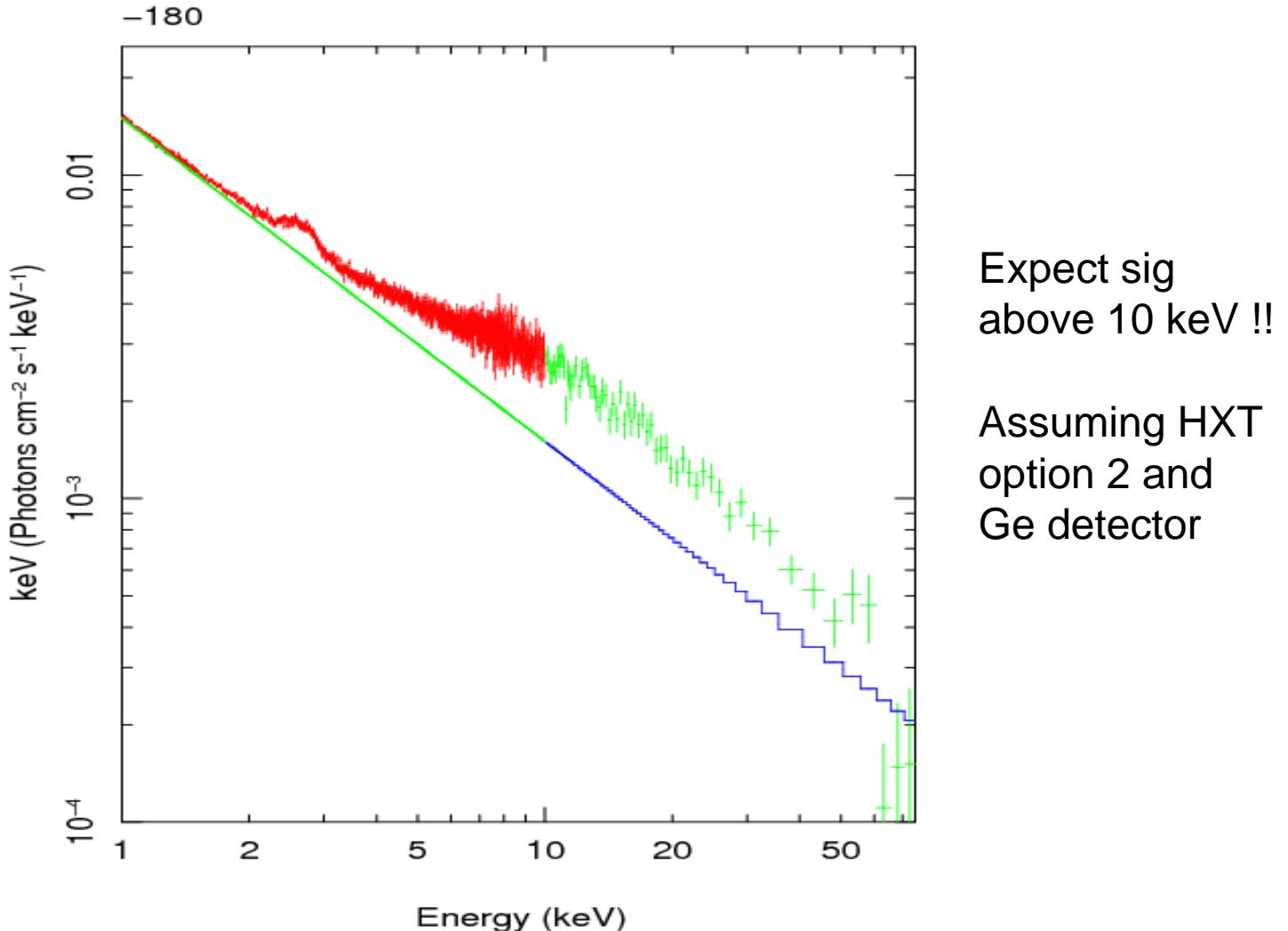
$t_{\text{orb}}=4 \text{ ks}$

$8 \times 500 \text{ s}$

Simulation Case 2: NGC 3516

$M=2.3\times 10^7 M_{\odot}$

$F_{2-10} \sim 5\times 10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1}$



$t_{\text{orb}}=4 \text{ ks}$

Some of our favorite AGN

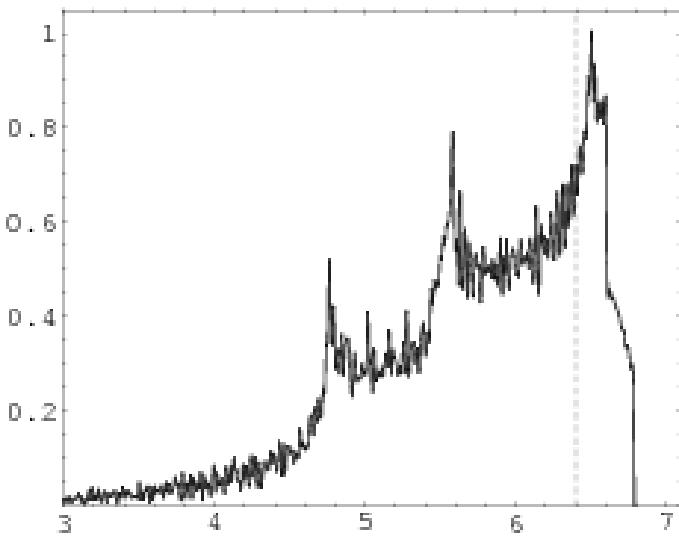
	t_{10rg} (ks)	$F_{2-10} 10^{-11}$ erg/cm 2 /s)
NGC4151	10	10
MCG-5-23-16	71	9
NGC 3783	29	7
IC4329A	10	7
NGC5506	2	7
NGC 3516	23	5
MCG-6-30-15	2	4
NGC7314	5	4
NGC4051	2	2
Mkn 766	5	2
Mkn 841	101	1

-bright objects with mass $> 10^7 M_\odot$ ideal

-phase-resolved spectroscopy for lower mass objects...

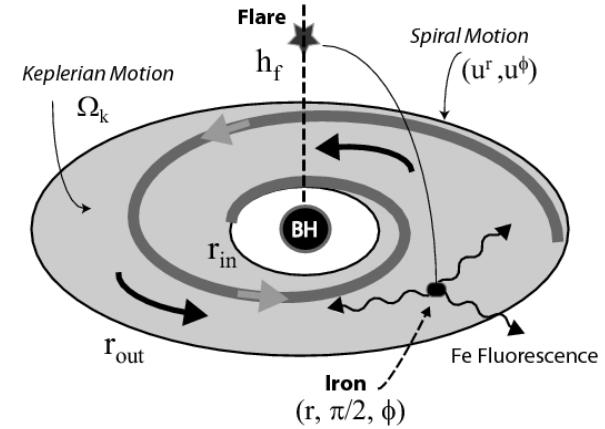
Fe lines from Spiral Density Waves in Kerr metric

MHD instabilities can induce spiral density waves.... Fe K profiles determined by spiral velocity field & location of magnetic flares

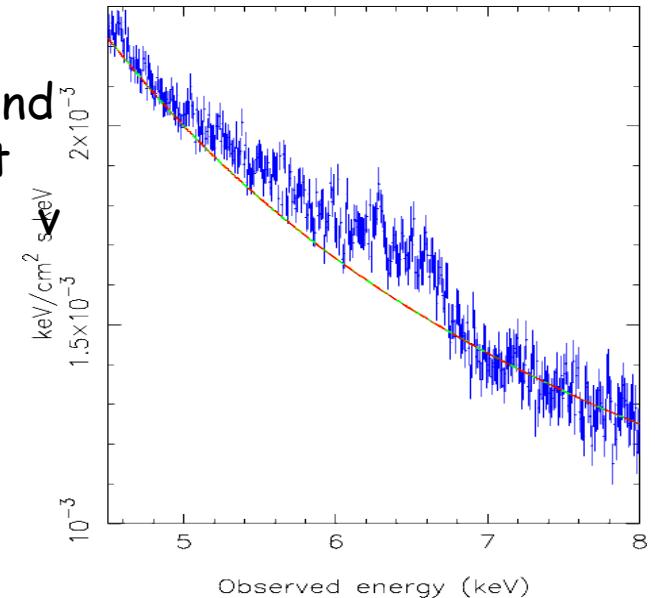


Predicted profiles depend on
-tightness of spiral pattern
-azimuthal angle etc

Fukumura & Tsuruta 2004



$Kr=0.7$,
tightly wound
pattern out
to $30\ rg$,
 $< 0.1c$
 $80\ ks$
 $F \sim 5 \times 10^{-11}$



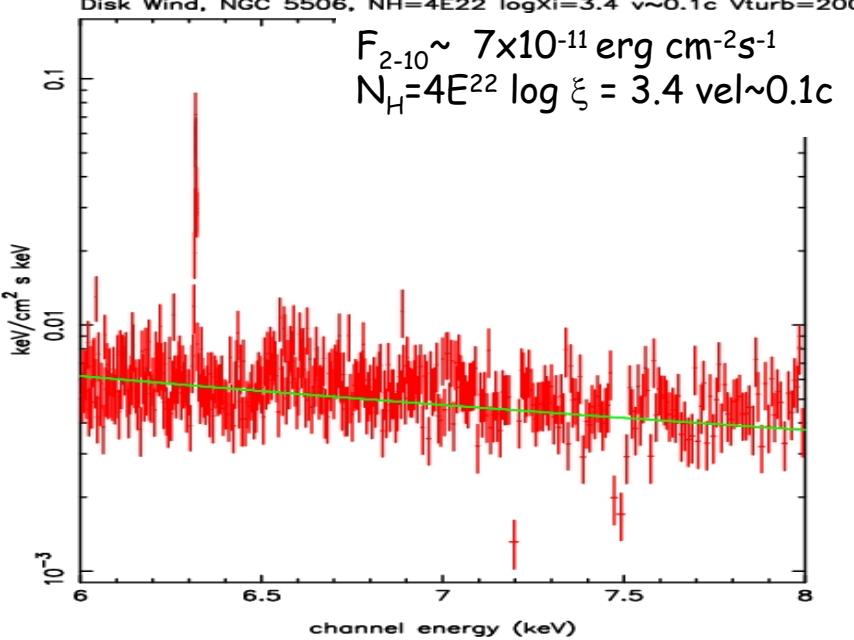
A note on the absorbers.....

Aside from being resolved so we can see the broad disk line...absorbers also interesting in their own right...

NGC 1365 shows Fe XXV - XXVI absn lines, $N_H \sim 5 \times 10^{23} \text{ cm}^{-2}$ var vel 1000-5000 km/s $\rightarrow r \sim 50-100 R_s$ (Risaliti et al 2005, 2006)

Numerous X-ray absorbers thought to arise v close to central BH

-blown off accⁿ disk (e.g. NGC 4151; Kraemer et al 2005; Mrk 766 Miller et al 2006)



Con-X - track absn line energy/flux down to 1-2 ks for brightest AGN ($\sim t_{\text{orb}} @ 6r_g$ in NGC 5506)

100 eV absn line 6.97 keV $\sigma \sim 80 \text{ eV}$
XMS \rightarrow flux to +/-11% in 1 ks

Trace kinematics & conditions of gas very close to BH for
-accretion rate/mass loss rate etc
-launch radii
-acceleration mechanism

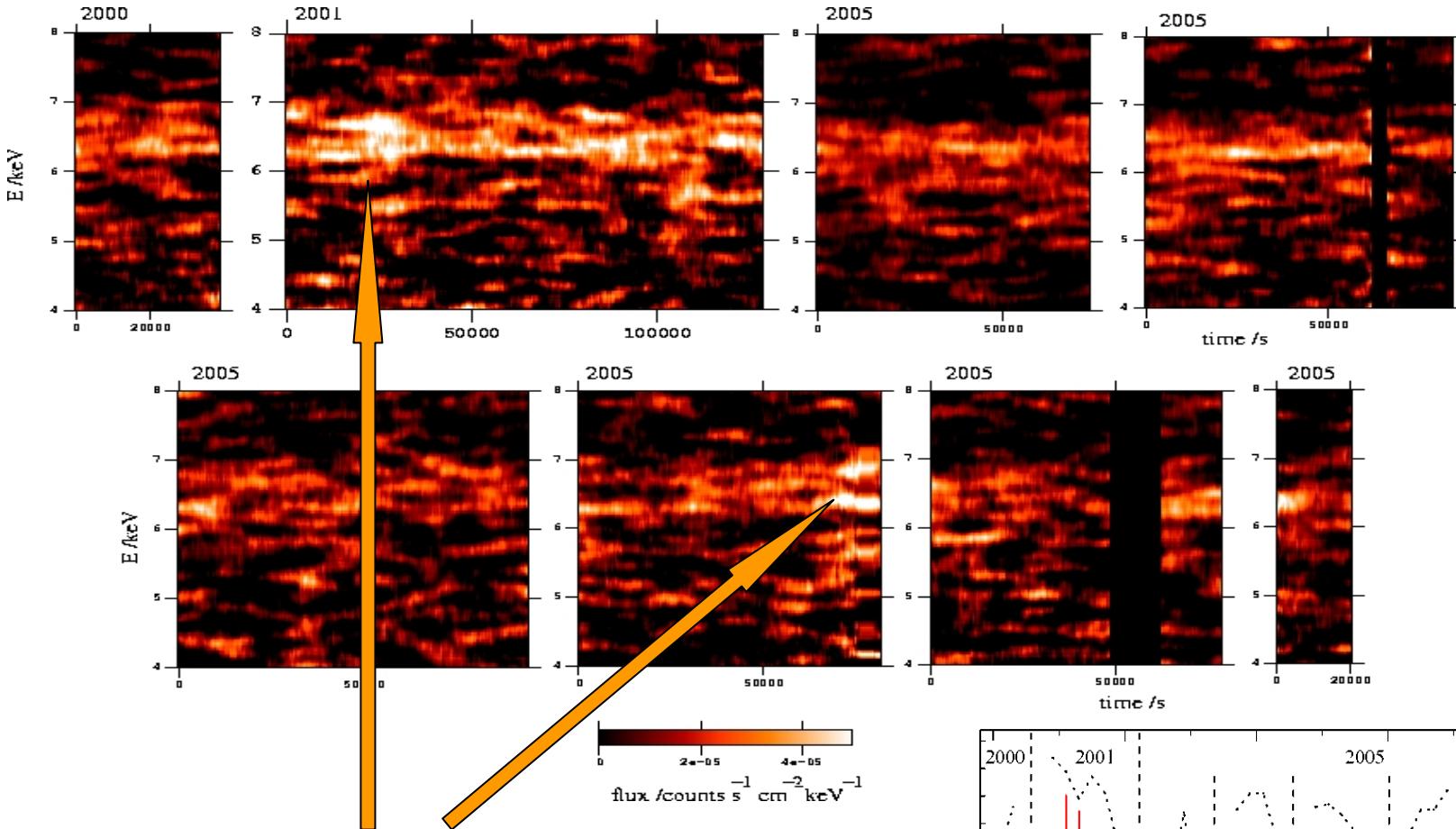
Summary

Con-X absolutely essential to get at core science

To understand accretion disks/physics in the strong gravity regime - combine Con-X obsn of broad Fe profile, integrated across the disk with information from hotspots, produced by instabilities in that disk

Con-X gets us down to radii where we can distinguish BH spin, for a number of AGN

Expectations include: test GR, understand SMBH accretion systems, BH mass derivations, disk tomography, accretion/expulsion rates & mechanisms/AGN feedback, BH growth/evolution



High-flux

Can diagnose
disk from line
variations -
seen when
source flux high

